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Farmers and their groves: Will cost inefficiency lead to land use change?

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1. Introduction

The land reform introduced by the Soviet-imposed government in Poland following WWII re-distributed land from some large estates among farmers, while creating a sizable state-owned farm sector on selected nationalized domains. The seizure of large private estates also involved the nationalization of forests within the natural part of an estate. The state-owned forest sector expanded greatly although the share of forests in the total country's area shrunk. The expansion of state-owned forested areas was accompanied by the rapid expansion of the state forest service, which had already been functioning prior to World War II. By 1985, for example, the state forest service employed 131,000 personnel. The number of employees gradually declined reaching 25,000 in 2009 (Kancelaria Senatu 2010) and continued to decrease in 2010. Only in 2011-14 did the state forest service employment increase slightly reaching the 2009 level (GUS 2015).

The transition to the market-driven economy in 1989-1990, left the forest service largely unchanged despite fundamental shifts in ownership of other state-owned assets, especially the state farm sector. While the state farm sector was promptly liquidated, forests remained in the government domain. The state farm sector sustained by government support under the centrally-planned economy (Florkowski et al. 1986; 1988) could not compete with the family farm sector once the administered price and subsidy system was abolished. Large, inefficient state farms were divided into original estates and leased or sold to farmers. The state forest service, in turn, benefitted from freeing prices. Distorted wood and lumber prices subjected to administrative control were abolished with the adoption of the market as the resource allocation mechanism in 1989. Market pricing increased forest service revenues. The primary disturbances faced by the forest service were periodic administrative shifts from one ministry to another. Currently, the forest service is administered by the Ministry of the Environment.

The reallocation of land away from the state to the private sector and subjecting agricultural production to market economy mechanisms forced new and old owners to reconsider farming of less productive land. Price liberalization resulted in a one-time increase of prices in 1989-1991. The inflation rate was 585.5 percent in 1990 and 70.1 percent in 1991 (Barbone 1992). Price increases led to a decrease in food demand creating a surplus of all types of food, a phenomenon on a scale unknown in Poland in decades of the centrally-planned economy. Farmers faced not only a contraction of food demand, but unfamiliar competition from imported food. The latter was the result of abolishing the monopoly of the state on international trade. Price re-adjustments and weak food demand were associated with the change in environmental policy in the country. Environmental policy was focused on the protection of land and landscape, among others, and stimulated the reforestation of poor quality agricultural land. As a result, land classified as Vth (i.e., Va and Vb) and VIth quality (according to Polish land quality classification (Zawadzki 2002)) could be planted with trees with government assistance. The goal of the policy was to increase the total forested area in Poland, but the result was also the permanent withdrawal of poor quality arable land from production. A number of farmers joined the program and planted trees, benefitting from government subsidies. The program created a substantial privately-owned forested area.

It is plausible that the primary motive of farmers in participating in the program of planting trees was the eligibility for subsidies, while not having to till land that was not suitable for agricultural production. However, since the program was implemented, there has been the lack of a study that examined the effects of reallocating arable land to forestry. Can the reallocation of land, besides helping to achieve the goal of increasing the share of forested land, increase the efficiency of farms? Farmers were unlikely to re-allocate all their land to forest, but only that of the lowest quality and eligible for the subsidy, especially once the food market started to recover in the first half of the 1990s.

Private forests help to achieve important policy goals. First, Poland has a relatively lower share of forested land than many other EU countries and forests are viewed as an important element of a sustainable environment. An increase in forested areas remains a major objective of environmental policies. Second, a non-productive effect of expanding forested area is binding of CO_2, while forest-based resources provide feedstock that contributes to the use of renewable energy to the country's total energy balance. Laws passed in recent years aim at increasing renewable energy's share in total energy produced in the country to 14% by 2020. Increasing domestic agricultural production not only satisfies food security needs, but generates surplus and forces changes in the farm sector. The average farm size has been steadily increasing in Poland in recent decades and the number of farmers has been declining. Most recently (as of April 2016), a new law has restricted agricultural land markets, granting priority of purchase of any farm land to a government agency over its sale to another farmer. Such laws may encourage retiring farmers and their non-farming heirs to retain land ownership. Relatively low-quality land may be converted into timber land, representing a long-term family investment, contributing to the goal of reforestation, and increasing renewable energy feedstock in the future.

To examine the performance of farms with forested land ownership in Poland, this study compares the efficiency of farms with any portion of their operated land as a forest with those that do not have any forested land. It is hypothesized that a farmer with a timber stand operates agricultural land of low quality and reforested the part of the lowest productivity. Farming such land is relatively costly because of the naturally low productivity of such soils, and farms with forested hectares have difficulty competing with farms that lack forested hectares (presumably operating more productive land). Owners of farms with forested hectares are likely to face the problem of transferring the farm operation within a family. High costs limit potential revenues, making farming unattractive for offspring. An option for retaining the ownership of land, besides renting, is reforestation of all owned hectares. Such an operation requires less input, while still generating income and is feasible for absentee ownership of heirs, who migrated to jobs in urban areas as rural areas depopulate in many regions. Reforestation rather than lease helps to achieve important national and EU policy goals. First, reforestation increases the share of forests in the country's total area, a currently stated goal of national policy. Second, a properly selected mix of species enhances the quality and future value of stands. Third, reforested areas become a source of feedstock in the renewable energy generation helping to achieve the EU-imposed mandate regarding the share of renewable energy in the total energy balance. Fourth, the withdrawal of low-quality agricultural land contributes to the national policy of enhancing the quality of the environment because it lowers the use of fertilizers, herbicides, and other inputs that could contribute to the pollution of soil, surface water, or air. Finally, the land is retained as a family asset. Renting the farmland is not likely to generate substantial revenues because of the low quality of soil and, possibly, reluctance of a renting party to invest in improving its productivity. The study focuses on cost efficiency, which was estimated using the fixed effects stochastic cost frontier model. A generalized multiproduct translog cost function represents the deterministic part of the cost function and is estimated using the Farm Account Data Network (FADN). The applied approach recognizes eight different farming operations distinguished in the FADN database and examines the effects of farms with forested hectares on cost efficiency in each type class. Furthermore, the study estimates the potential increase in the area of forests assuming all farms owning a stand and included in the FADN would reforest the operated land and provides an estimate of gain in total forested area of the country.

1.1 Forest ownership in Poland

Historically, forests were owned by nobility or royalty in Poland. After re-gaining independence following World War I, the government organized the state-owned forests as a commercial company on December 30, 1924 (Kikulski 2016), but it soon (in February 1924) was converted into the state forest service organization. Major changes followed World War II when all forests exceeding 25 hectares in size were nationalized. The combination of forest nationalization and re-shaping of Poland's borders meant that nearly 90 percent of forests was state-owned prior to 1989 and concentrated in the western and northern parts of the country.

In 2013, state-owned forested areas accounted for 81.1 % of the 9.177 million hectares of total forest area in the country (Leśnictwo 2014 2016). Not all state-owned forests are operated by the forest service. About 2% are national parks, nearly 1% represents communal forests, and the balance is owned by other government entities. The state forest service manages about 77% of the forested area. The total area of the country covered by forests, which amounted to 38% in 1920 (within post-WWI national boundaries) declined to 20.6% in 1945 (within post-WWII national boundaries), has reached 29.4% in 2013, or 0.1% more than a year earlier. The goal of national policy is to increase the share of forest to 30% of the country's total area by 2020 and 35% by 2050. The expansion of forest area must primarily come from the re-allocation of privately-owned agricultural land.

1.2 Expansion of privately-owned forests

Privately-owned forests accounted for 18.9% of all forests in Poland in 2013 (Leśnictwo 2014 2016). Under the centrally-planned economy, private forest areas were fairly stable because a larger parcel of land could have been owned only by farmers, who farmed every bit of it. Those who had forests (25 hectares or less) seldom were reforesting any of the arable land or pasture because the demand for food was insatiable and of the heavy dependence on own forage supply for livestock due to restrictions placed by the government on family farm access to commercial feed. The centrally-planned allocation system and distorted prices resulted in inefficiencies (Penn 1989) and those, in turn, encouraged farming of even the lowest quality land.

The adoption of the market economy and the fundamental economic, political, and social changes following the "Round Table" agreement in 1989 in Poland led to the reduction of the state's role in the economy. For example, in 1995, state-owned forested areas accounted for 82.9% of the total forested area in the country. The small portion of forests that remained private after nationalization were small patches of land owned by farmers, whose farms did not exceed the area limits set by the land reform act of 1945. Such groves were typically very small, seldom exceeding one hectare and often planted in a single tree species like pine or birch. The groves were planted on very poor quality soil, which presented a challenge for growing any agricultural crops or permanent pasture.

After the transition to a market economy in 1989, the state farm sector was gradually liquidated and the land sold or leased. The pressure on family farms to maximize production eased once market prices replaced government-controlled pricing and free trade was allowed, flooding the market with food products. In the 1990s, the government also introduced subsidies for reforestation of low-quality agricultural land in efforts to protect the environment. Private land owners, including farmers and buyers of land auctioned from the former state-farms, took advantage of the program. The share of privately-owned forests increased from 17.1% in 1995 (GUS 2000) to 18.5% in 2010 (GUS 2011) reflecting the faster rate of growth of privately-owned than state-owned forests in the increasing total forest area during that period. The withdrawal of poor-quality land from farming could be expected to increase efficiency. The issue that has never been examined is whether the farms that have a forest perform better than those without forested land. On one hand, withdrawing land from production may reflect a sound management decision to improve production costs and competitiveness, but on some farms forests might have been an intended source of fuel and possibly timber.

1.3 Farmers as forest owners

The nationalization of forests that exceeded 25 hectares following WWII limited any ownership to farmers, who operated small stands. Moreover, the severely regulated land market (Penn 1989) and ideologically-driven priority of state ownership made an expansion of a farm by land purchase impossible under the centrally-planned regime. The expansion of forest area was managed by the state forest service. Not until the reduction of restrictions placed on land markets and the liquidation of the state farm sector following the 1989 change of the economic and political system could private individuals purchase a sizable parcel of land. Land market liberalization combined with the general liberalization of the economy created conditions to consider land reforestation by farmers and private land owners.

Private forest share varies across the 16 administrative districts (voivodships) of the country. In eastern and central voivodships, the share of private forests reported by farmers is larger than in western or northern areas. Private forests' share in eastern-most voivodships of Lubelskie and Podkarpackie represents 36.9% and 16.9%, respectively, and the largest share of

43.3% is reported in Mazowieckie Voivodship (GUS, 2012). In the western voivodships of Lubuskie, private forests are 1.2% of the total, while in Zachodniopomorskie they account for 1.6%.

In Poland, the average private forest stand covers 1.17 hectares. The largest average forest is owned by farms in Podlaskie Voivodship (2.67 hectares) while the smallest area of 0.59 hectares is in Slaskie Voivodship. The aforementioned Lubelskie and Podkarpackie farms average 1.30 hectares and 1.02 hectares, respectively. The average farm in Mazowieckie Voivodship had 1.49 hectares of forested area (if it owned any).

The farm forested area needs to be considered in the context of total operated land. The average farm operated 10.49 hectares in 2015 (Agencja Restrukturyzacji i Modernizacji Rolnictwa. 2015a). The current average farm size has been strongly influenced by the land reform and forest nationalization following WWII. Relatively small farms and the largest private forest ownership is in the voivodships where the state farm sector's presence was limited, i.e., in eastern (Lubelskie), central (Mazowieckie, Swietokrzyskie, Lodzkie), and southeastern regions (Podkarpackie). The average farm size in those regions is considerably smaller than in other parts of Poland, while the land quality is poor in most of them. Such farms are unlikely to continue their existence because they do not provide opportunities to generate income adequate to sustain a household. The majority of those regions also experiences depopulation and once the current operators retire, the heirs may consider reforestation as an option that retains the land in the family, permitting absentee ownership and requiring less resources. Reforestation of low quality farm land will contribute to the share of forested land helping to achieve the stated policy goal of reaching 35% of total country forested land surface by 2050 without burdening the state forest service. Additionally, private forests could become a source of feedstock for production of energy from renewable sources either through production of biogas or pellets. Renting land to other farmers, although feasible may not be as attractive in the long run because of inefficient farms of low-quality land. Knowledge of farm relative cost efficiency helps to estimate the size of potential transfer of land from agricultural use to forestry.

2. Materials and method

2.1 Cost frontier estimation approach

Improved input use makes an inefficient farm more productive (Langemeier 2010). The current study examines cost efficiency to empirically verify the extent it may be lacking among farms with forest stands in Poland. The stochastic cost frontier framework applies an index with value range from zero to one as the cost efficiency measure. According to that measure, the index of most efficient farms equals one and such farms are positioned on the frontier function. Kumbakhar and Knox Lovell (2003) propose the following fixed effects stochastic cost frontier model written in the following way where i denotes farms and t the periods:

$$(1) \qquad \ln E_{it} = \ln C(Q_{it}, W_{it}, \tau_t; \Omega) + v_{it} + u_i \ .$$

In equation (1), the observed expenditure $\ln E_{it}$ is in the logarithm and the deterministic cost function, $\ln C(Q_{it}, W_{it}, \tau_t; \Omega)$ that depends on the outputs Q_{it}, the input prices W_{it}, a deterministic trend τ_t that captures technological change, and a vector of parameters Ω. All the variables except the trend are in logarithms.The statistical error, v_{it}, is independent and identically distributed with mean zero and variance $\sigma_v{}^2$. The time invariant inefficiency term u_i is positive.

Prior to estimation, it is necessary to select the functional form for the deterministic part of the stochastic cost frontier (i.e., $\ln C(Q_{it}, W_{it}, \tau_t; \Omega)$). Following Caves, Christensen, and

Tretheway (1980), this study applies a generalized multiproduct translog cost function. The latter imposes fewer a-priori restrictions than alternative functional specifications. Caves, Christensen, and Tretheway (1980) note that in the context of multiproduct estimation, a farm may not generate a specific output causing the logarithm used in the translog function to produce an error. A Box-Cox transformation can then substitute for the logarithm of the output terms. This study applies $f(Q)=Q$ as a hybrid between the translog function and the quadratic function. The cost function for n inputs and m outputs is:

$$(2)\qquad \ln C(Q_{it},W_{it},\tau_t;\Omega)=\alpha_0+\varphi_0\tau_t+\varphi_0\tau_t^{\,2}+\sum_{j=1}^{n}\alpha_j\ln W_{jt}+\tfrac{1}{2}\sum_{j=1}^{n}\sum_{k=1}^{n}\beta_{jk}\ln W_{jt}\ln W_{kt}$$
$$+\tfrac{1}{2}\sum_{j=1}^{m}\sum_{k=1}^{n}\delta_{jk}f(Q_{jit})\ln W_{kt}+\sum_{j=1}^{m}\gamma_j f(Q_{jit})+\tfrac{1}{2}\sum_{j=1}^{m}\sum_{k=1}^{m}\rho_{jk}f(Q_{jit})\cdot f(Q_{kit}).$$

The stochastic cost frontier has to satisfy the properties of any cost function (Chambers 1988). The imposition of price homogeneity and symmetry conditions in (2) followed from placing restrictions on the parameters (3):

$$(3)\qquad \sum_{j=1}^{n}\alpha_j=1;\ \sum_{j=1}^{n}\delta_{jk}=0;\ \sum_{j=1}^{n}\beta_{jk}=0;\ \sum_{k=1}^{n}\beta_{jk}=0;\ \sum_{j=1}^{n}\sum_{k=1}^{n}\beta_{jk}=0;\beta_{jk}=\beta_{kj}\ .$$

The inefficiency coefficient is assumed to be time invariant and was estimated using a fixed effects panel data model of a stochastic cost frontier estimated (Schmidt and Sickles 1984; Kumbakhar and Knox Lovell 2003; Greene 2008). However, the use of a fixed effect model precludes the use of time invariant variables in estimation. To overcome this restriction, in the context of cost function estimation, the parameters linked to input prices are estimated from the cost share equations, where the inefficiency terms (i.e., the fixed effect terms) do not appear.

The equation to be estimated, with the intercept $\alpha_{0i}=\alpha_0+u_i$ is:

$$\text{(4)} \qquad \ln E_{it} = \alpha_{0i} + \varphi_0 \tau_t + \varphi_0 \tau_t^{\,2} + \sum_{j=1}^{n} \alpha_j \ln W_j + \tfrac{1}{2} \sum_{j=1}^{n} \sum_{k=1}^{n} \beta_{jk} \ln W_j \ln W_k + \tfrac{1}{2} \sum_{j=1}^{m} \sum_{k=1}^{n} \delta_{jk} f\left(Q_{jit}\right) \ln W_k$$
$$+ \sum_{j=1}^{m} \gamma_j f\left(Q_{jit}\right) + \tfrac{1}{2} \sum_{j=1}^{m} \sum_{k=1}^{m} \rho_{jk} f\left(Q_{jit}\right) \cdot f\left(Q_{kit}\right) + v_{it}.$$

The dataset does not contain input prices for each farm, but it is common in cross section estimation to assume that all farmers face identical prices (e.g., Alvarez and Arias 2003). However, in a cost function estimation applying panel data, prices are introduced under the assumption that all farmers face the same input prices within a year (i.e., across farms), while allowing prices to change over time.[1]

Equation (4) was estimated for five inputs (i.e., n) and three outputs (i.e., m). Because of the high number of parameters subject to estimation, the system of $(n-1)$ cost shares was initially computed using Iterative Seemingly Unrelated Regression Equations (ISURE). Thus, the constraints in (3) were imposed. This step provided the values for all the terms in (4) that were associated with input prices. Second, all the remaining parameters of the cost function, except the fixed effect terms (i.e., output terms not associated with prices) were estimated using the within estimator (ordinary least square applied to the variables expressed as deviations of the means by farm as in Hsiao, 1986). Finally, the fixed effect terms used in the construction of the relative cost efficiency indices were estimated from equation (4) by evaluating the function at the mean value of the variables by farm (Atkinson and Cornwell 1993; Kumbakhar and Knox Lovell 2003; Pierani and Rizzi 2003).[2]

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[1] In a different context, similar assumptions can be found in the estimation of demand systems, where price elasticities are sometimes estimated from time series because of the lack of variability of prices in cross section datasets (Hsiao 1986, p.206).

[2] The farm level estimated fixed effects used to compute the relative cost efficiency indices were assumed to be constant over time due to the short period covered by the sample (in the best case, information was available for some farms for eight years) (Kumbakhar and Knox Lovell 2003, p. 170).

As shown in Kumbhakar and Knox Lovell (2003), the relative cost efficiency index (CEI_i) for a sample size N was computed as equation (5) based on the estimated fixed effect intercepts (i.e., $\hat{\alpha}_{0i}$), where for the most cost efficient producers it has a value equal to one:

$$(5) \qquad CEI_i = \exp\{-(\hat{\alpha}_{0i} - \min_i\{\hat{\alpha}_{0i}\})\} \qquad i = 1,..., N .$$

The results of the cost function estimations for eight farm type categories and for the whole sample provided insights into cost efficiency differences. For each farm type, the study reports the calculated elasticities of substitution among five input categories (Table 1A). The majority of the calculated elasticities are statistically significant[3].

2.2 Data

Data used in this paper are from the FADN database. Initiated in 1965, the data collection goal was to verify the effect of the Common Agricultural Policy (CAP) of the European Union (EU) on farm income. Farm participation is voluntary. As is often the case in voluntary participation, the Polish farms that are likely to be omitted are those with less commercial production, less income, and having relatively high costs due to low quality of land. FADN specifies data collection regions for every country participating in the program and in the case of Poland there are four macro-regions, each consisting of four voivodships (administrative districts overlap exactly with FADN subregions in the case of Poland).

The FADN annually records a wide range of financial (e.g., assets, liabilities), economic (e.g., crops, stocks), and physical (e.g., livestock number, crop area) data from a selection of farms realizing commercial sales across the EU applying the same accounting principles. Polish farms sharing the information represent well the farms engaged in commercial agricultural

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[3] Results of estimation are available from the authors upon request.

production. Farms are classified in each of eight farm types as defined in the FADN database; (e.g., mixed cropping farms, livestock farms).

In the case of Poland, data were available only since the 2004/05 production year (after the country's accession to the EU on May 1, 2004). The voluntary participation of each farm causes some farms to drop from the panel and the available set is unbalanced panel data. The data are annual observations for the period 2004/05-2011/12. The unbalanced panel applied in this study included 19,455 farms, representing 93,916 observations. The study examines the cost efficiency of farms of all types included in the sample.

Costs and outputs by farm type were computed directly from the FADN data. The estimation of cost functions requires input prices; however, a shortcoming of the FADN data for the estimation of cost functions is that it only presents input expenditures and not the prices paid for inputs (or their used quantities). Therefore, Eurostat's input price indices data (base year 2005) were used for agricultural materials, energy, and capital as an estimate of those prices paid by farmers over the study period. Labor and land input prices were estimated from the FADN data.

3. RESULTS

3.1 Cost efficiency scores

Prior to the estimation of the effect of having any forested area on the efficiency score, price elasticities for inputs were calculated for each farm type and for the whole sample (Table 1A) using the estimation result of the cost efficiency functions. The vast majority of input elasticities has the expected signs and is statistically significant. The only own price elasticity that is positive and significant is in the case of energy input in "specialist grazing livestock."

This type of highly specialized farming operation is likely limited to mountainous regions (seasonal grazing of sheep herds) of Poland and the energy use is atypical.

The efficiency scores (i.e., the fixed effects) were analyzed to establish the differences between all farms in the sample and for each farm type category. The comparison is made within the group or within the total sample. Each farm's score is compared against the most cost efficient farms located on the frontier for each farm type category. Histograms of the scores reveal substantial variation within each group in terms of cost efficiency. There is a heavy concentration of farms in the lower portion of the index 0-to-1 range, suggesting the discrepancy between the most cost efficient farm in each group and in the total sample, and the large portion of farms lagging in efficiency. Figure 1 illustrates the distribution of index scores for the mixed cropping farms, a fairly common type of enterprise in many regions of Poland. The majority of farms in the sample have scores below one-third of the most efficient farm in the category. The discrepancies within other farm types tend to be even bigger in the FADN sample data used to calculate the scores. Overall, a significant number of farms in all categories are cost inefficient and, presumably, not competitive in the foreseeable future. Many such family farms will probably withdraw from active farming and will face a decision about how to manage the land. For those operating low-quality lands, reforestation can be a viable option, especially given the government reforestation support program.

3.2 Effect of forested area on farm economic performance

The presence of any forested area in a farm's total area was further examined by regressing the cost efficiency scores on the economic size of a farm and a binary variable capturing ownership of forested hectares (Table 2). The economic size measure is listed in FADN data and defined by the European Commission (European Commission 2011). The measure is the standard gross margin expressed in euros. The set of equations representing each farm type and the whole sample was estimated using the heteroscedasticity-consistent OLS. The values of the adjusted R square are reasonable given the cross-sectional nature of the data with the exception of the “Mixed cropping” category. Still, even in the latter equation the coefficients are statistically significant with expected signs, i.e., the positive effect of the economic size and the negative effect of the ownership of forested hectares.

The results strongly indicated, both in aggregate and considering estimates by farm type, that most of the farms with forest land were relatively less efficient than farms without them in each farm type category. Indeed, the efficiency scores are positive due to farm size, which effects offset the typically negative effect of the presence of forested areas (Table 2). The dummy variable coefficient indicating the presence of forested land in the total land operated by a farm has a statistically significant and negative sign with the exception of the category “Specialist field crops.” The latter result is plausible because farms specializing in field crops are likely to maximize the arable land they operate and any forested area was likely quite small. Clearly, the presence of forest lowered the efficiency scores suggesting that farms with such land were less cost efficient than those without a stand as expected.

4. DISCUSSION

Important policy implications stem from the results. Because the average farm size has been steadily increasing (although it remains relatively small, especially in some regions – see Table 3) in response to decreasing farm numbers and elimination of state farms in Poland, as long as commercial agricultural production contracts in some marginal areas without creating a shortage of food or agricultural commodities, there is an opportunity to reallocate land from its current uses to reforestation on farms that already manage small stands. The speed of reallocating land will, however, depend greatly on the ability of forested land to generate a stream of income that would replace the current payments to each farm hectare under the EU CAP. Reforested land would have to generate comparable returns.

The rate of transferring land from agricultural use to reforestation is unsatisfactory if the goal of expanding the forested area by 680,000 ha is to be achieved in the period 2001-2020. Before 2004 (Poland entered the EU on May 1, 2004), the transfer was supported under a government plan. During the period 2007-2013, Poland benefited from the funds transferred from the EU and provided subsidies for private land owners (Table 4). Under that scheme, a farmer could qualify for a one-time subsidy ranging from 4160 PLN to 6260 PLN depending on the proportions of planted conifers and deciduous trees as well as the topography of the land (Konieczny 2008; Agencja Restrukturyzacji i Modernizacji Rolnictwa. 2016a). The subsidy also favored seedlings that had been pre-treated. An additional 2590 PLN per hectare was available for fencing. For the first five years after planting, a farmer qualified for remuneration for performing the recommended cultural practices. The payment ranged from 970PLN to 1360 PLN per hectare per year (Table 4). Another subsidy was paid to farmers who could document that at least 25% of their income originated from agricultural production. These farmers could receive 1580 PLN for each reforested hectare for a period of 15 years after planting. The payment compensated for lost revenue after reallocation of land away from farming. As a result, assuming the lower boundary of the range of payments (excluding subsidies for fencing and repellant application), a farmer could receive a total of 6710 PLN per hectare annually in the first five years after reforestation.

The subsidies available for the period 2014-2020 differ (Table 4). Although, in general, the overall payments tend to be higher (Agencja Restrukturyzacji i Modernizacji Rolnictwa.

2016b), the compensation for the lost income from agricultural production will be paid for 12 years, rather than 15 years after reforestation. Additionally, the maximum land area that a private owner can reforest under the current subsidy program has been lowered from 100 ha to 20 ha. The reduction of the area should not constrain the transfer of land because, as shown earlier, the average farm size in Poland is well under that limit. What seems to be more important is the amount of funds that the government allocates to support reforestation.

Given the number of farms that have forested hectares and tend to be already cost inefficient, agricultural land is at the upper limit of areas that can potentially be reforested. Using the number of farms with forested hectares in the 2011 FADN data, the average farm size, and the average forest area per farm (Table 3), the area that could be reforested is 45,595 hectares. In Lodzkie Voivodship, characterized by the smallest share of forest in total area, the additional land transfer could involve 3,424 ha. The potential reforested privately-owned area based on FADN sample corresponds to about 27% of the 159,300 hectares of land reforested between 2001 and 2014 under the 2001-2020 national reforestation program that projected an additional of 680,000 hectares of forest by the expiration year. The number of farms with forested land in the 2011 FADN sample represents less than 0.4% of all farms in Poland. It is estimated that 38% of the 14.13 mln farms (Rocznik Statystyczny Rolnictwa 2015) own some forested land already and the potential area for reforestation is substantial.

4.1 Rye and potato production changes

The transfer of agricultural land to reforestation will cause a decrease in agricultural production. The land quality on farms with forests is categorized as the “rye-potato” rotation, meaning that these two crops dominate the rotation (the other rotation is “wheat-sugar beet” and requires higher quality land). Therefore, if the land is withdrawn from agricultural use, the production of rye and potatoes, among other crops, may decline. Assuming that at any given time one half of the agricultural land transferred to reforestation from the farms in the FADN data, the area planted with rye decreases by an estimated 23,000 hectares. The actual volume of rye produced per hectare varies across the 16 regions, but using the example of a five-year average of rye yields (2010-2014) in Lodzkie Voivodship, the average decline in the produced volume is 8,492 tons (or 0.003% of Poland's rye crop in 2014). Similarly, if the other half of the withdrawn area is no longer planted with potatoes, the corresponding decrease in potato production is 83,477 tons, assuming the five-year average yields are similar to those from Lodzkie Voivodship (or, about 1.12% of Poland's potato crop in 2014). Lodzkie Voivodship is among the regions with the smallest forested area and low potato yields in Poland. The relative importance of rye and potatoes for the domestic supply of food and feed has been declining for years and the estimated volume is unlikely to cause shortages. For example, in 2000, the potato crop amounted to 24.2 mln tons, but steady decline in demand for potatoes led to shrinking production (7.4 mln tons in 2014). Moreover, since the reforestation program is voluntary, the effects at the local and farm level will be gradual and will respond to local demand and supply conditions implying a relatively measured change in rural society.

4.2 Potential contribution to carbon sequestration

Reforestation of an additional 45,595 hectares of land (based on farms in the FADN 2011 panel) will contribute to carbon sequestration. The amount of absorbed CO_2 by hectare of a forest depends on several factors including the species of tree, its age, location (for example, urban vs. forest), latitude, etc. but it is estimated at $38m^3/CO_2$ or 10 tons of carbon annually. Obviously, the benefits will be smaller for a period of time after planting, but eventually, the total area of transferred land has the potential to bind about 1.73 million tons of CO_2 or 0.46 mln tons of carbon each year. The actual amount will be somewhat smaller because it will depend on other factors including the health of the forest or the incidence of forest fires. Selected management practices that will provide wood biomass for renewable energy generation will offset some of the carbon sequestration gains. Although modern furnaces utilizing wood and wood products substantially reduce the gas emission, they do not completely eliminate it and, therefore, the provided carbon sequestration estimates represent the upper limit of possible changes. An additional benefit stems from the oxygen released by each tree. Nevertheless, the net benefit of reforestation for limiting greenhouse gas emission will be meaningful.

5. CONCLUSIONS

Poland strives towards increasing the share of forested areas in the total area of the country, which declined substantially due to WWII's destruction and redrawing of the country's borders. Private forests, which accounted for small stands for decades due to government's restrictive policies, have gained in importance after the transition to a market economy in 1989. Since then, the growth of privately-held forested land outpaced that of the state forests. Forests also play an important role in the country's efforts of carbon sequestration and contribute feedstock to generate energy from renewable resources. Poland, like all other EU members, has assumed an obligation to increase the share of renewables in energy production and faces a specific target in 2020.

This study examined the potential contribution of family farms to the growth of forested areas. The reallocation of land away from agriculture to forestry is hypothesized to take place foremost on farms that already own forested land. The presence of forested hectares reflects the low quality of land and high production costs. The calculated cost efficiency indexes for eight farm types showed that the majority of farms are inefficient as compared to farms located on the cost efficiency frontier. Additionally, the study established that farms with forested hectares have lower efficiency scores in all farm type categories. It is, therefore, plausible that farms with forested hectares are less competitive and likely to terminate agricultural production. Such farms have an opportunity to reforest their land, while becoming eligible for government subsidies under the reforestation program. A total of approximately 45 thousand hectares could become reforested if all farms already operating forests (as reported in the FADN data) transfer all their agricultural land. Although the calculated area is the upper limit of farms which currently already have forested land (and are in the FADN panel), it is likely that many other farms would follow that example. Consequently, privately reforested area is likely to increase contributing to achieve multiple national policy goals.

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Table 1. Descriptive statistics of farms in FADN sample with the forested area and share of forested area in total operated farm land by voivodship, Poland, 2011.

Forested area	No of observations	Mean	Std. dev.	Variance	Minimum	Maximum	CV
All the sample (2011)							
Forest (ha)	5643	2.28	4.95	24.55	0.01	145.00	2.17
Share of forest	5643	0.07	0.09	0.01	0.00	0.89	1.21
Łódzkie							
Forest (ha)	499	1.62	2.29	5.23	0.01	24.00	1.42
Share of forest	499	0.07	0.09	0.01	0.00	0.76	1.19
Mazowieckie							
Forest (ha)	1045	2.14	2.94	8.63	0.01	38.54	1.37
Share of forest	1045	0.09	0.09	0.01	0.00	0.73	0.98
Małopolskie							
Forest (ha)	253	1.83	5.55	30.77	0.01	84.74	3.03
Share of forest	253	0.13	0.13	0.02	0.00	0.67	1.07
Śląskie							
Forest (ha)	104	1.55	1.80	3.24	0.06	10.30	1.16
Share of forest	104	0.06	0.08	0.01	0.00	0.34	1.37
Lubelskie							
Forest (ha)	605	1.83	6.15	37.81	0.02	145.00	3.37
Share of forest	605	0.07	0.07	0.00	0.00	0.47	1.02
Podkarpackie							
Forest (ha)	129	1.84	2.68	7.16	0.01	22.98	1.45
Share of forest	129	0.08	0.09	0.01	0.00	0.50	1.12

Świętokrzyskie							
Forest (ha)	152	1.41	2.11	4.43	0.05	17.20	1.49
Share of forest	152	0.06	0.07	0.01	0.00	0.40	1.14
Podlaskie							
Forest (ha)	712	3.13	6.22	38.69	0.01	140.00	1.99
Share of forest	712	0.09	0.08	0.01	0.00	0.55	0.90
Wielkopolskie							
Forest (ha)	560	2.46	3.92	15.37	0.02	45.00	1.60
Share of forest	560	0.08	0.09	0.01	0.00	0.52	1.21
Zachodniopomorskie							
Forest (ha)	155	2.28	5.12	26.22	0.01	46.00	2.24
Share of forest	155	0.03	0.05	0.00	0.00	0.31	1.61
Lubuskie							
Forest (ha)	84	3.11	6.36	40.44	0.06	43.71	2.05
Share of forest	84	0.04	0.05	0.00	0.00	0.28	1.36
Dolnośląskie							
Forest (ha)	238	1.64	2.75	7.57	0.01	16.00	1.68
Share of forest	238	0.03	0.06	0.00	0.00	0.44	1.71
Opolskie							
Forest (ha)	167	2.80	8.99	80.80	0.01	97.34	3.21
Share of forest	167	0.04	0.08	0.01	0.00	0.89	2.23
Kujawsko-Pomorskie							
Forest (ha)	390	2.34	4.27	18.21	0.03	34.00	1.82
Share of forest	390	0.05	0.08	0.01	0.00	0.56	1.47

Warmińsko-Mazurskie							
Forest (ha)	283	2.01	3.02	9.14	0.01	30.00	1.51
Share of forest	283	0.05	0.06	0.00	0.00	0.48	1.36
Pomorskie							
Forest (ha)	267	4.13	9.45	89.31	0.01	84.40	2.29
Share of forest	267	0.09	0.13	0.02	0.00	0.81	1.57

Table 2. Heteroskedasticity consistent OLS results of cost efficiency scores for eight farm types and the whole FADN sample with the effect of owning forested area, Poland, 2004/05-2011/12.

	Specialist field crops				Specialist horticulture				Specialist permanent crops			
Variable	Coefficient	Std. error	t-statistic	p-value	Coefficient	Std. error	t-statistic	p-value	Coefficient	Std. error	t-statistic	p-value
Constant	0.0034	0.0014	2.39	0.0168	0.0192	0.0064	3.01	0.0027	0.0660	0.0030	21.84	0.0000
Size	2.39E-07	2.61E-08	9.16	0.0000	1.34E-06	1.16E-07	11.56	0.0000	1.35E-06	1.21E-07	11.17	0.0000
Forest area	-0.0076	0.0051	-1.50	0.1347	-0.1163	0.0291	-3.99	0.0001	-0.0963	0.0427	-2.26	0.0242
Adj. R sq.	0.7504				0.5665				0.4803			
F-statistic	7004.78				521.13				347.58			
	Specialist grazing livestock				Specialist granivore				Mixed cropping			
Constant	0.0745	0.0083	8.97	0.0000	0.1471	0.0055	26.82	0.0000	0.0830	0.0080	10.41	0.0000
Size	5.25E-07	2.02E-07	2.60	0.0095	6.36E-07	7.89E-08	8.07	0.0000	3.52E-06	3.85E-07	9.14	0.0000
Forest area	-0.0705	0.0159	-4.42	0.0000	-0.0839	0.0287	-2.92	0.0035	-0.1089	0.0269	-4.05	0.0001
Adj. R sq.	0.4389				0.4022				0.5859			
F-statistic	1873.99				1122.17				513.81			
	Mixed livestock				Mixed crops-livestock				All the types together			
Constant	0.2718	0.0056	48.58	0.0000	0.0536	0.0015	35.23	0.0000	0.0207	0.0009	22.90	0.0000
Size	4.44E-07	1.69E-07	2.63	0.0084	3.09E-07	3.40E-08	9.10	0.0000	2.59E-07	1.89E-08	13.71	0.0000
Forest area	-0.2744	0.0226	-12.14	0.0000	-0.1095	0.0068	-16.14	0.0000	-0.0436	0.0031	-14.19	0.0000
Adj. R sq.	0.1164				0.4884				0.5009			
F-statistic	332.09				3459.36				9756.81			

Table 3. Average farm size and farm size change 2006-2011 by voivodship.

Country/Voivodship	Average farm size in ha, 2011	% change 2006-2011	Number of observations in 2011 FADN database	Average area of forested land in ha
Poland	10.36	8.25	5643	2.28
Dolnośląskie	16.01	9.43	499	1.62
Kujawsko-Pomorskie	15.04	3.94	1045	2.14
Lubelskie	7.46	4.34	253	1.83
Lubuskie	20.82	10.28	104	1.55
Łódzkie	7.49	4.17	605	1.83
Małopolskie	3.86	6.63	129	1.84
Mazowieckie	8.52	4.28	152	1.41
Opolskie	18	7.66	712	3.13
Podkarpackie	4.54	7.33	560	2.46
Podlaskie	12.22	4.27	155	2.28
Pomorskie	19	5.61	84	3.11
Śląskie	7.01	13.06	238	1.64
Świętokrzyskie	5.49	5.98	167	2.80
Warmińsko-Mazurskie	23.07	2.53	390	2.34
Wielkopolskie	13.47	2.05	283	2.01
Zachodniopomorskie	30.7	8.21	267	4.13

Sources: Own calculations based on Agencja Restrukturyzacji i Modernizacji Rolnictwa. (2015b) and FADN data.

Table 4. Forms of subsidies available for land reforestation under the 2007-2013 and 2014-2020 programs, per ha of reforested land.

Subsidy	Amount in PLN for the period	
	2007-2013	2014-2020
One time payment[a]	4160-6260	4984-7385
Fencing of the reforested area:		
One-time payment	2590	-
Per meter of fence	6.50	8.82
For staking each planted tree	-	1132
Annual payment for cultural practices paid for 5 years[b]	970-1360	794-1628
Annual repellent application to protect the plantings from wildlife damage	190-700	424
Loss of income compensation	580[c]	1215[d]

Note: Subsidies provided for the area not exceeding 100 ha during the period 2007-2013, or not exceeding 20 ha during the period 2014-2020.

[a] The exact amount depends on proportions of decisions vs. evergreen species, configuration of land, and the use of pre-treated seedlings.

[b] State forest service inspection determines the exact payment within the range.

[c] Annually, for 15 years after filing documentation that income from farming represented at least 25% of income.

[d] Annually, for 12 years.

Source: Based on Agencja Restrukturyzacji i Modernizacji Rolnictwa. (2016a) and Agencja Restrukturyzacji i Modernizacji Rolnictwa. (2016b)

Appendix

Table 1A. Input substitution elasticities for eight farm categories and the whole FADN sample farms owning forested area, Poland, 2004/05-2011/12..

	Elasticities					Elasticities				
	Materials	Energy	Labor	Land	Capital	Materials	Energy	Labor	Land	Capital
	Specialist field crops					Specialist horticulture				
Materials	-1.421	0.041	0.576	0.370	1.157	-3.055	1.302	0.813	1.989	1.375
	(-22.401)	(0.341)	(14.164)	(8.169)	(19.958)	(-24.129)	(7.440)	(9.789)	(4.114)	(13.848)
Energy		-1.588	0.526	0.139	0.035		-2.867	0.825	-0.479	-0.359
		(-2.478)	(10.232)	(2.226)	(0.249)		(-3.469)	(5.896)	(-0.349)	(-0.799)
Labor			-1.921	0.727	0.577			-1.467	-0.379	0.274
			(-31.401)	(12.246)	(16.529)			(-15.083)	(-0.989)	(3.741)
Land				-6.749	0.372				17.124	-2.124
				(-60.890)	(8.519)				(3.178)	(-2.750)
Capital					-2.005					-1.476
					(-28.284)					(-5.456)
	Specialist permanent crops					Specialist grazing livestock				
Materials	-4.774	0.220	0.790	2.273	1.311	-0.630	-0.802	0.359	0.659	0.563
	(-14.475)	(0.527)	(11.357)	(4.481)	(9.783)	(-10.216)	(-7.017)	(12.609)	(11.981)	(8.888)
Energy		-6.954	0.474	0.166	0.865		2.418	0.326	-0.022	-0.001
		(-4.232)	(6.237)	(0.236)	(3.740)		(3.740)	(8.858)	(-0.282)	(-0.006)
Labor			-1.109	0.232	0.467			-1.126	0.538	0.651
			(-21.629)	(1.527)	(11.562)			(-31.127)	(9.507)	(25.821)
Land				-1.242	-1.178				-12.792	0.317
				(-0.790)	(-4.966)				(-72.035)	(5.736)
Capital					-1.084					-1.543
					(-14.561)					(-19.531)

Table 1A. Cont.

	Elasticities					Elasticities				
	Materials	Energy	Labor	Land	Capital	Materials	Energy	Labor	Land	Capital
	Specialist granivore					Mixed cropping				
Materials	-0.145	-0.336	0.344	0.583	0.137	-2.758	0.929	0.614	0.907	0.911
	(-4.153)	(-3.591)	(7.345)	(7.064)	(1.864)	(-6.977)	(1.306)	(6.595)	(2.555)	(3.825)
Energy		-6.305	0.503	0.240	2.425		-0.040	0.309	0.583	-1.117
		(-5.306)	(5.811)	(1.177)	(8.663)		(-0.014)	(2.502)	(1.046)	(-2.106)
Labor			-1.930	0.293	0.617			-0.786	0.573	0.353
			(-17.216)	(2.049)	(9.138)			(-11.503)	(3.731)	(5.597)
Land				-16.895	0.076				-11.557	-0.194
				(-38.939)	(0.457)				(-14.310)	(-0.771)
Capital					-1.756					-0.763
					(-9.115)					(-3.821)
	Mixed livestock					Mixed crops-livestock				
Materials	-0.667	-0.545	0.604	0.534	0.381	-0.676	0.035	0.387	0.755	0.414
	(-11.589)	(-4.707)	(19.300)	(7.037)	(5.218)	(-11.821)	(0.294)	(13.068)	(13.897)	(6.530)
Energy		-3.453	0.442	0.132	1.292		-5.353	0.400	0.172	1.077
		(-3.727)	(9.564)	(0.977)	(6.422)		(-7.293)	(10.540)	(2.017)	(7.503)
Labor			-1.184	0.441	0.429			-0.990	0.317	0.470
			(-29.567)	(6.480)	(14.640)			(-26.294)	(6.026)	(18.461)
Land				-14.633	0.456				-11.619	0.342
				(-53.060)	(4.857)				(-74.569)	(5.793)
Capital					-1.685					-1.614
					(-14.764)					(-18.537)

Table 1A. Cont.

	Elasticities				
	Materials	Energy	Labor	Land	Capital
			All the types		
Materials	-0.986	-0.375	0.491	0.773	0.932
	(-34.327)	(-6.423)	(28.911)	(22.972)	(31.560)
Energy		0.639	0.377	0.027	-0.066
		(1.601)	(14.476)	(0.455)	(-0.757)
Labor			-1.309	0.463	0.538
			(-62.947)	(14.807)	(36.924)
Land				-11.264	0.031
				(-115.976)	(0.881)
Capital					-1.984
					(-48.626)

Figure 1. Example of the average cost efficiency indexes calculated for the farm type “Mixed cropping” using FADN data for the period 2004/05-2011/12.